Diesel vehicle market-share reduction analysis

Executive summary

The Government's Air Quality Plan identifies transport emissions as a key contributor, and an area where technology transformation can reduce NOx emissions in particular. The Plan focuses especially on the real impact of diesel vehicles on air quality and discusses the most appropriate policy support for transitioning to ultra-low and zero emission vehicles.

The aim of this paper is to contribute to this discussion by setting out a costed and realistic phase out trajectory for diesel vehicles in three different market segments (cars, LCVs and HGVs) using Government assumptions and market insight from BVRLA members.

The paper develops four main conclusions:

a. Policymakers should consider transport segments separately in terms of its diesel phase out strategy, to allow for the different technical capabilities, product availability and cost characteristics of vehicle alternatives.

b. From a social cost-benefit analysis perspective, an overly rapid reduction in diesel market-share would be economically detrimental, particularly in the case of LCVs and HGVs. The analysis provides a cost-effective market-share reduction rate for the car sector, and suggests that a gradual rate (less than 7% a year) provides the greatest social net benefit.

c. Support for new mobility services (through a mobility credits scheme) can provide a broader range of social benefits than private diesel vehicle replacement, as advocated by scrappage schemes. Promoting the use of car rental, car clubs, public transport and other forms of shared transport can reduce congestion, and encourage urban residents to use more sustainable modes of transport.

d. A consistent policy framework is needed across the UK to avoid placing additional compliance complexity and cost on an industry which operates between urban areas.

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This report was produced by Ecuity Consulting LLP and was commissioned by the BVRLA. The analysis presented is based on publicly available data and technology assumptions which are referenced throughout the report and in the appendix. The paper is intended for general dissemination in the hope of encouraging debate and discussion between industry, decision makers and policy stakeholders. While Ecuity considers the information and opinions given in this report to be reasonable based on currently available information, Ecuity offers no warranty or assurance as to the accuracy and completeness of the information contained in this report.

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Context – changing modes of transport

As urban populations continue to grow, the persistent concentrations of dangerous and illegal levels of pollutants in UK cities needs to be addressed. Poor air quality creates significant health issues, and resultant economic costs – with poor quality costing the UK economy an estimated £2.7 billion in 2012[1]. The Government has identified transport emissions as a key contributor, and an area where technology transformation can reduce NOx emissions.

Local road traffic sources are responsible for 80% of roadside NOx concentrations. Of this segment, diesel cars, vans (LCVs), and HGVs emit over three-quarters of this pollution[2]. These vehicles have understandably been identified as problematic by the Government in the evolving air quality plan. Indeed many civil society groups have called for new policies to reduce the number of diesel vehicles operating in areas with the highest population density.

A transformation away from diesel vehicles should lower NOx levels in cities – all else equal. However, such a move away from current market conditions, especially when expedited, can be challenging and costly. This paper estimates the costs of a rapid shift away from diesel. These include the additional operating costs borne by commercial users having to operate alternative vehicles, and the current EV capital cost premium over internal combustion engine (ICE) vehicles. The analysis develops understanding of the relationship between the diesel vehicle market-reduction rate, reduced NOx benefits, and the costs involved with pursuing such a transformation.

In addition to the barriers mentioned, Government policy has the potential to create stranded diesel vehicle assets which would be a significant cost to society. The relationship between policy, a reduction in diesel market-share and demand for vehicles in the second-hand market is complex. This analysis focuses on new diesel vehicle sales reduction, and has therefore not modelled lost residual value. However, BVRLA members note the risk of severe regulation reducing their ability to resell diesel vehicles. Some members note that such costs borne by commercial operators could be passed onto customers, and others acknowledge risks to profitability which would impact their ability to invest in newer technology and vehicles.

The analysis uses social cost benefit analysis (based on the Government's Green Book methodology) to assess the merit of different rates of diesel market-share reduction applied to three vehicle segments: cars, LCVs and HGVs over a 10-year period from 2018-2027. The modelling assesses the costs and benefits of moving away from a business-as-usual (BAU) market scenario, and quickening a transition away from diesel vehicles. These costs and benefits are aggregated over a 10 year period to give a net cost/benefit figure (in net present value terms).

Social cost-benefit analysis

- A standardised methodology used to assess the costs/benefits of different policy proposals. Sums these up over a 10 year period to give a net figure (NPV).
- Takes account of impacts to the consumers and the economy, as well as changes to pollution levels (NOx and CO2 emissions) – which are monetised.
- For consistency, the analysis uses the Government's Green Book methodology.

Interventions should be targeted to provide the greatest social benefit for the least cost. This analysis recognises that NOx emissions must be tackled cost-effectively, and looks for the optimal market reduction rates for each of the three segments (cars, LCVs and HGVs) separately.

[1] DEFRA (2015) *Valuing the Impacts of Air Quality on Productivity*. Available from: https://uk-air.defra.gov.uk
[2] DEFRA (2017) *UK plan for tackling roadside nitrogen dioxide concentrations – Technical report*. Available from: https://www.gov.uk/

This report develops four key conclusions:

1. Policy should target diesel vehicle reduction in transport segments where good alternatives are available, and those alternatives have an impact on NOx emissions.
2. Whilst the transition from diesel vehicles is necessary, the market-reduction rate should be steady, allowing the supply chain and consumers to transition to alternative technologies without incurring too many costs.
3. In order to ensure greatest value for money, policy should seek to support behaviour change such as the increased use of car sharing models, which can facilitate a shift away from old diesel vehicles, and also lower vehicle mileage and congestion.
4. A consistent policy framework is needed across the UK to avoid placing additional compliance complexity and cost on industry.

1. Targeting transport sectors

Travel patterns

Air pollution is a particularly severe problem in urban areas, where population density is greatest and subsequent exposure is widest. Therefore it is a recognised challenge to target mitigation policies on the vehicles which travel in urban centres most readily. Figure 1 below provides a breakdown of the location of vehicle traffic in Great Britain as at quarter 1 2017. In aggregate, British vehicles travel over 319 billion miles per year, but there is a clear difference in the travel patterns displayed by cars and LCVs when compared to HGVs. Car and LCV traffic display a similar rural/urban split (approximately 1/3 of traffic on urban roads), but HGVs are far less likely to travel in populous areas of the country.

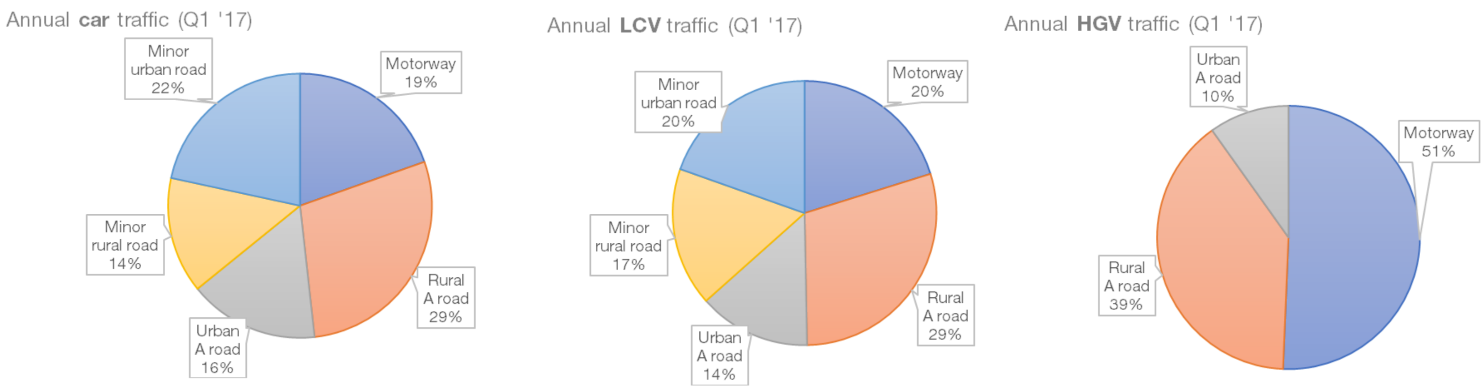


Figure 1 - average annual vehicle traffic by location (DfT, 2017)

DEFRA publish a range of social damage cost values which provide an estimation for the cost to society (health etc.) from the emission of 1 tonne of NOx. Whilst these figures are best used for small marginal changes to emissions, they provide a guide to the relative value of reduced air pollution from a reduction in diesel vehicle usage.

As suggested, the social damage cost figure varies by emission location, with NOx emitted in urban areas being more costly than the same quantity produced in a rural area (see table 1 below).

Therefore the monetised damage cost (£/tNOx) associated with car traffic will be higher than the cost of 1 tonne of NOx emitted by an HGV based on the typical traffic patterns shown in figure 1.

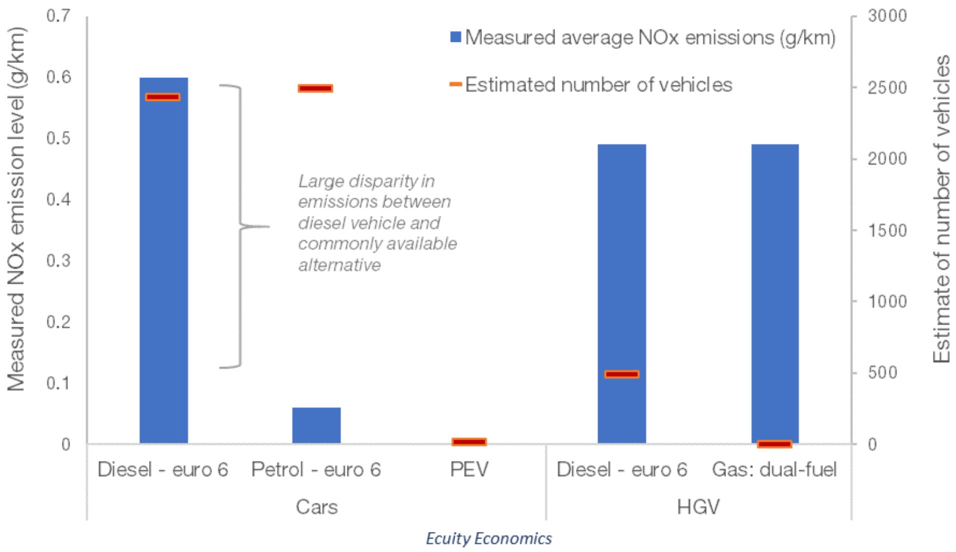
Table 1: NOx social damage cost (£/tNOx, 2015) (DEFRA)	
Urban medium - transport	£28,788
Rural areas	£7,829

Alternatives and usage requirements

Each vehicle segment has a differing range of diesel-alternatives. Figure 2 illustrates some of the typical alternatives available for the car and HGV markets. Whilst diesel is the dominant fuel type for trucks and large commercial vehicles, there are currently few alternatives which can cost-effectively operate and produce lower NOx emissions. Indeed the research into gas-powered HGVs provides a mixed view as to the benefit of these alternative fuel types against diesel, in regard to NOx emission reduction[3].

Whilst LCV's operate in urban areas at a similar rate to cars, there are fewer low emission alternatives. For instance, battery-packs come with range restrictions and can add significantly to vehicle weight thereby reducing commercial vehicle payload, whilst gas alternatives are hampered by sparsely located refuelling stations and higher upfront costs.

For the car sector, real-world emission testing has suggested that there is a significant benefit to switching away from diesel vehicles, and indeed there are a number of alternative fuel types. It is important to note that the best performing diesel vehicles can meet euro 6 standards and perform to the equivalent levels of leading petrol models in a real world setting[4]. Most immediately petrol is almost cost-comparative with diesel, and electric vehicle (EV) purchase prices are falling rapidly. Indeed this analysis uses market research[5] to model the falling price of EVs over the 10 year period examined, and bases an increasing EV market-share on National Grid's Future Energy Scenarios.



[3] Ricardo AEA (2016) *The role of natural gas and biomethane in the transport sector.* Available from: https://www.transportenvironment.org/
[4] EQUA Index (2017) *The EQUA Air Quality Index.* Available from: http://equaindex.com/equa-air-quality-index/
[5] Bloomberg New Energy Finance (2017) Available from: https://www.bloomberg.com/

Figure 2 - car/HGV segment comparison of diesel vehicle alternatives, and typical real-world NOx emission factors[6]

The lack of clear cost-comparative alternatives for larger commercial vehicles which reduce emissions substantially, means that it is relatively more expensive for society to tackle NOx pollution by targeting HGVs. This cost is known as the abatement cost and can be compared with the relative benefit of reducing 1 tonne of NOx, which is approximately equivalent to the social damage cost (see table 1). Figure 3 represents the abatement cost figures derived from the modelling exercise – where diesel vehicle market-share is reduced annually in each model by 5%. Note that HGV alternatives (biomethane and dual fuel gas alternatives) have not been included here as NOx savings are inconclusive[7].

Tackling NOx emissions by reducing diesel car market-share is shown to be the most cost-effective means of tackling air pollution, but the rate of diesel phase-out should also be considered.

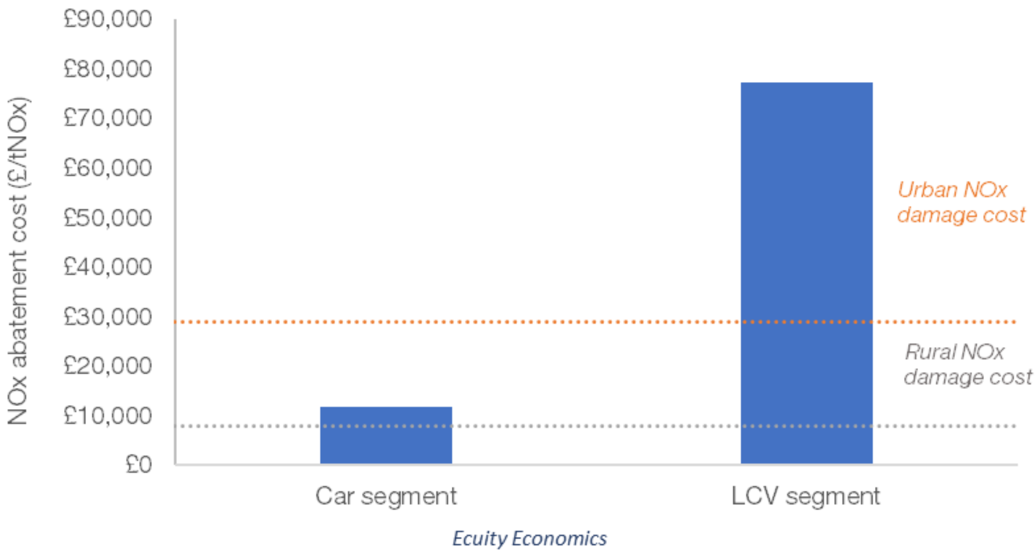


Figure 3 - NOx abatement cost (£/tNOx) for the car and LCV modelled vehicle segments (modelling result for a 6% market-share reduction and DEFRA damage cost)

i. ***Government policy should recognise the distinct challenges and opportunities at play in each transport segment. This analysis demonstrates that Government policy should focus diesel market-share reduction on cars and small LCVs, rather than large HGVs.***

2. Speed of transition away from diesel

As can be seen in figure 4, diesel and petrol cars have each enjoyed an approximate 49% market-share over the last 3 years, with some increased uptake in new registrations of petrol cars seen in 2016, potentially as a response to the changed Government stance on diesel. The modelling considers how quickly the UK should move away from these 'business-as-usual' (BAU) trajectories for cars, LCVs and HGVs separately.

[6] Uses NOx emission factors from European Environment Agency (2016) and Ricardo AEA (2016). Number of vehicles data from DfT (2017)
[7] Ricardo AEA (2016) *The role of natural gas and biomethane in the transport sector.* Available from: https://www.transportenvironment.org/

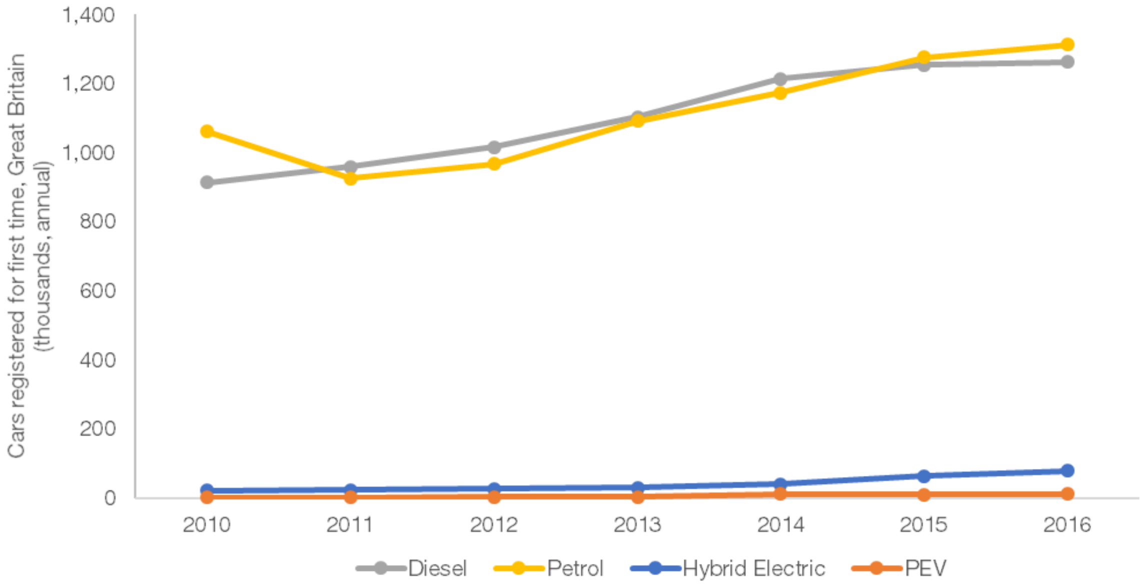


Figure 4 - annual new car registrations by fuel type in Great Britain (DfT, 2017)

Each transport segment has a number of challenges which limit the speed at which UK consumers can cost-effectively transition away from diesel vehicles. For gas-powered commercial vehicles, the lack of refuelling stations (currently around 20) is challenging and can add additional operating costs (taking extra time to travel to refuelling stations reduces productive hours). This is compared to over 8,000 petrol stations in the UK supplying diesel. This additional cost has been modelled and included in the analysis.

Whilst EV costs are falling, purchase prices are still higher than diesel vehicles and supply is constrained by a supply chain scaling production to meet record levels of demand. Many industry commentators expect EV car upfront costs to hit parity with internal combustion engine alternatives in the 2020's, and our model takes BNEF's forecast of vehicle price trajectory[8].

Figure 5 considers the optimal diesel car market-share reduction rate, based on the assumptions expressed in the annex. The analysis demonstrates the social NPV[9] increases initially as NOx levels are reduced, therefore the Government should act to address diesel car consumption. Here the marginal benefit of reducing one unit of NOx (the damage cost) exceeds the marginal cost (additional capital and infrastructure costs of EVs and operating/CO2 costs of petrol cars).

Figure 5 illustrates that a gradual 6-7% annual diesel market share reduction rate – the equivalent of taking 5-6 million diesel cars off the road between 2018-2027 – is optimal for the economy. A quick transition (past 7%) to EVs and petrol alternatives means that the cost of reducing a unit 1 tonne of NOx exceeds the benefit. A more gradual phase-out rate would be more socially optimal, as capex/infrastructure/operating costs fall over time with improvements to EV performance and price.

[8] Bloomberg New Energy Finance (2017) Available from: https://www.bloomberg.com/
[9] NPV = net present value. The sum of all costs and benefits accrued over the 10 year period, discounted to 2017 prices.

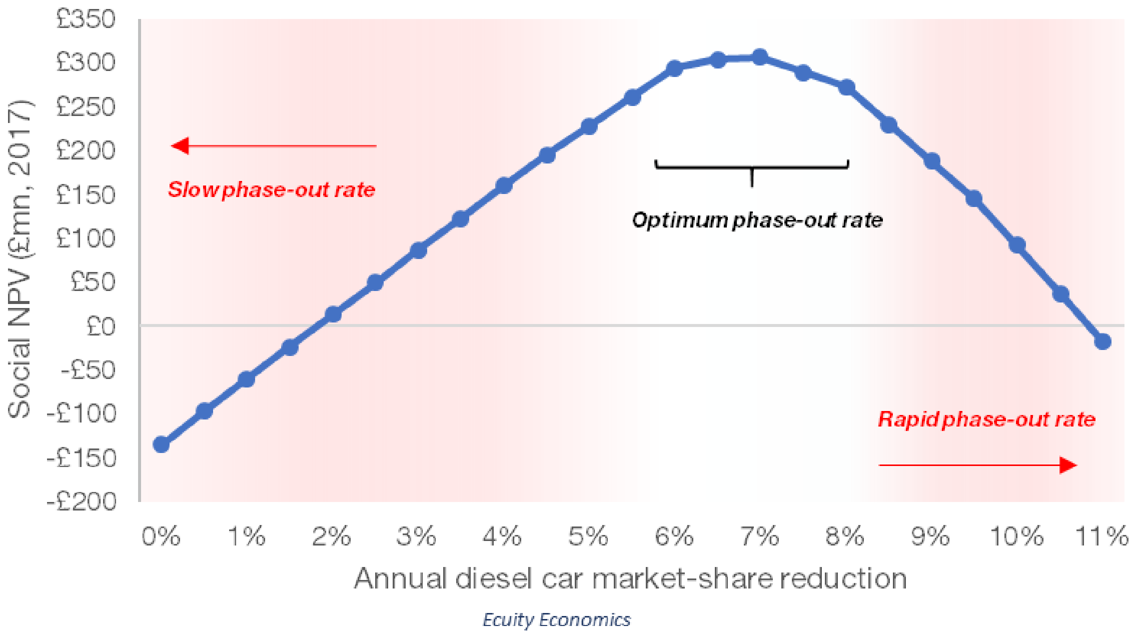


Figure 5 - results of social cost/benefit analysis by rate of diesel car, market-share reduction (modelling result)

ii. Government should promote a gradual diesel market-share reduction, and support the transition by investing in infrastructure to help reduce the costs of operating alternative vehicles.

3. Policy impact and value for money

This paper has commented on the need for regulation to reduce transport emissions, the benefit of targeting segments separately, and also the need for a gradual and staggered diesel market-share reduction. Additional to this, the characteristics of the government policy designed to facilitate this transition is important.

Some of the policy proposals such as a diesel car scrappage scheme help tackle NOx by promoting technological change, but do less to incentivise behavioural change. BVRLA has proposed the establishment of a mobility credits scheme which would provide subsidised car sharing or public transport in return for a scrapped diesel car.

The mobility credits policy proposed here is more cost-effective than a scrappage scheme, and provides greater additionality through behavioural change; which could over time reduce the number of private cars driven on UK roads. Crucially the promotion of shared transport and car clubs can both lower NOx and help tackle congestion which is very problematic in certain city regions and local councils.

The analysis models a car-sharing scenario where 10% of new ‘alternative’ cars (bought instead of diesel) are used as car sharing vehicles. Market research suggests that car club members travel fewer miles per year[10], and the analysis reflects this saving.

[10] Carplus (2016) *Carplus annual survey of car clubs*. Available from: https://www.carplus.org.uk/

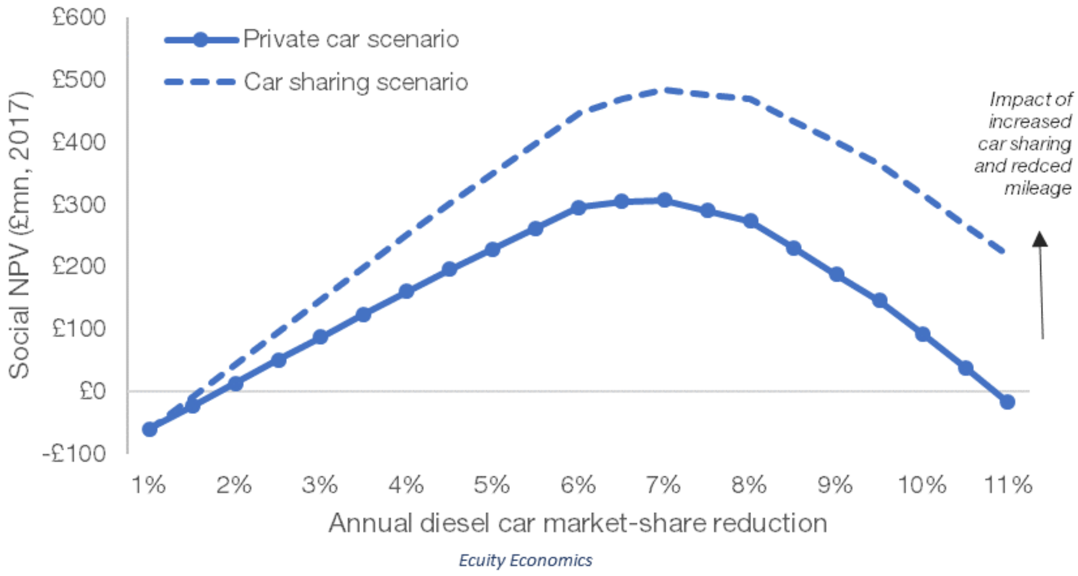


Figure 6 - impact of greater car sharing on car model NPV (modelling result)

4. Supporting national companies with consistent policy

The average city dweller's car is parked for 97% of the time[11] and can be considered an underutilised asset. The UK could more intelligently utilise transport assets to help address congestion on UK roads. Companies offering car leasing, sharing and mobility services can promote more efficient vehicle use and lower mileage. In addition, the typical car club/leasing fleet is more environmentally friendly than the UK average and can support the shift to a newer and cleaner vehicle stock[12].

The Government can support these companies which offer UK-wide mobility services by ensuring that policy frameworks and parameters are consistent across the country. Whilst it is recognised that policy should distinguish between cities and rural areas for example, it is important that many different policy solutions are not simultaneously created. This would create undue compliance complexity and cost for national businesses.

Increasing regulatory burdens can be expected to lower national economic performance[13], whilst providing no additional policy benefit – i.e. for the same impact on air pollution. Indeed multiple regulation regimes would likely create significant inefficiencies within businesses through higher administration costs, and restrictions on asset allocation in line with diverse local regulations. Instead a national framework would create certainty for industry and reduce compliance costs significantly. This economically preferable outcome could be achieved whilst promoting the same amount of NOx reduction.

iii. A fragmented policy approach could create unintended consequences, with vehicles potentially being shifted from a high regulation area to another with more lax legislation. Central Government can play a role to ensure that the policy framework and parameters remain relatively consistent amongst city regions.

[11] Europcar (2010) *Stress and the Chassis – The Cost of Dormant Urban Motors to Our Pockets*.
[12] BVRLA (2017) *Fleet Air Quality – Factsheet*. Available from: http://www.bvrla.co.uk
[13] OECD (2012) *Measuring Regulatory Performance*. Available from: https://www.oecd.org/gov/

Conclusions and policy implications

This report supports the position that the Government should act to reduce dangerous air pollution and NOx emissions from transport. However the analysis presented suggests that an intervention should target the market segments where alternatives are most cost-effective, and provide good NOx abatement potential. In addition to this, the intervention should seek to reduce diesel market-share gradually. A rapid phase-out rate is challenging to achieve and creates additional costs.

Transport segment	Diesel phase-out rate	Number of diesel vehicles reduced over 10 years	NOx emissions saved (tNOx)	Discounted benefits (£mn)	Discounted costs (£mn)	NPV (£mn)
Car model	Low (2%)	950,000	21,915	£457	-£444	**£13**
	Central (6%)	5,091,644	108,603	£2,294	-£1,999	**£295**
	High (10%)	7,256,215	171,443	£3,540	-£3,448	**£92**
LCV model	Low (2%)	296,776	1,451	£86	-£149	**-£63**
	Central (6%)	907,551	4,142	£262	-£534	**-£272**
	High (10%)	1,554,889	6,815	£447	-£955	**-£508**
HGV model	Low (2%)	28,303	N/A	£75	-£249	**-£174**
	Central (6%)	84,909	N/A	£226	-£747	**-£521**
	High (10%)	141,516	N/A	£377	-£1,246	**-£869**

Table 2 - results from modelling exercise (modelling results)

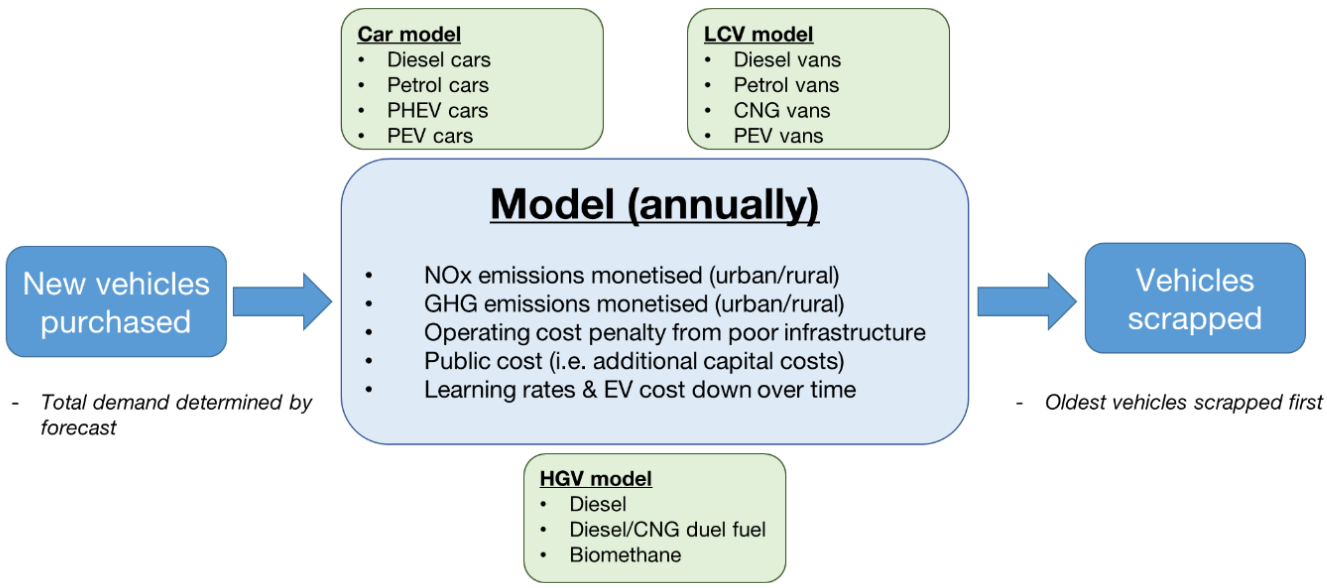
Table 2 summarises the results from the modelling carried out for this paper. The results suggest that the Government policy is better targeted at car segments where alternatives are more readily available and impactful, than commercial vehicles which additionally travel more often on rural roads. Table 2 suggests that Government policy which delivers a 6% annual reduction in diesel car market-share would take over 5 million diesel vehicles off the road (against the counterfactual projection), and reduce NOx emissions by 109,000 tonnes over the 10 year period considered. Our modelling suggests that this gradual rate of diesel car phase-out (6% annually) is more socially optimal than a very rapid reduction (10% annually), and reduces the cost of abating NOx from £14,000/tNOx to £12,000/tNOx.

Finally, this paper suggests that the promotion of mobility services is a good way for the UK Government to support NOx emission reductions, with our analysis demonstrating that this scenario provides the greatest social net benefit. Indeed with many city planners wishing to tackle congestion and PM2.5 emissions as well as NOx, the reduction of road traffic would bring additional value for the UK economy. This can be promoted by supporting car sharing schemes, public transport, cycling and walking in urban centres. In order to most effectively tackle air pollution, many commentators have noted that vehicles numbers need to be reduced in conjunction with greening the UK's fleet[14].

[14] The Guardian (2017) *London should lead in showing electric cars will not tackle air pollution*. Available from: https://www.theguardian.com/

Annex – methodology and data assumptions

The graphic below provides an overview of the structure of the models used for this report. Each of the 3 models (cars, LCVs and HGVs) considers how an expedited diesel vehicle phase-out rate (reducing diesel market-share each year) produces additional costs and benefits for the UK economy. The methodology used to calculate the social NPV (see table 1) is consistent across the three models and 3 transport segments. However the technologies featured varies between models in-line with the most readily available alternatives currently to diesel. Whilst we recognise that there are a number of other technologies which could be commercialised over the next 10 years, this modelling considers those that are most readily available currently.



Residual value

This paper has highlighted the potential for severe regulation of diesel transport to create stranded assets, and significantly reduce the residual value of vehicles in the resale market. The analysis presented in this paper considers the costs and benefits of different rates of diesel market-share reduction. It is assumed that Government policy would expedite this move away from purchasing diesel vehicles, and towards alternatives.

This analysis does not model or make an assumption regarding the type of policy that would cause this shift, and other policies that the Government might support to improve air quality. It is therefore difficult to reliably estimate the impact on residual value of diesel vehicles. For example whilst a Clean Air Zone policy and an increased plug-in-car grant policy might both theoretically result in the same diesel phase out profile (e.g. reduced sales compared to EVs), the impact on residual car values might be very different.

Car model

The car model considers the social costs and benefits accrued from the shift away from diesel cars, to three alternative technologies: petrol, petrol hybrid cars, and battery electric cars.

Model parameters	*Value*	Comment	Source
Vehicle Demand Assumptions			
Number of cars registered - population	32.3mn (2018) - 34.3mn (2027)	Increases over 10 year period in line with increased population. 0.6 cars demanded per adult person.	DfT & ONS population projection
New cars registered per year	2.8mn - 2.9mn	Increases over 10 year period with increases in population	DfT
Cars scrapped per year	2.6mn - 2.7mn	Ecuity calculation based on increased demand for cars	Ecuity assumption.
Business as Usual (BAU) technology demand	(a) Diesel - 48%-38%, Petrol - 48%-38%, (b) PHEV 1%-16%, PEV 3%-8%	(a) Ecuity assumption based on DfT car licencing statistics over last 5 years (b) National Grid FES Consumer Power scenario	(a) Ecuity assumption (b) National Grid
EV car supply constraint (max % of annual demand)	10% - 50%	Represents increased production of batteries and EVs over the 10 year period	Ecuity assumption.
Diesel phase-out model: new LCV technology demand	Petrol 96% (2018) - 53% (2027) EVs 4% (2018) - 47% (2027)	As diesel is phased-out, the proportion of demand attributed to alternatives	Ecuity assumption.
Operating Cost Assumptions			
Annual average mileage (km) (a) Private cars (b) Shared cars (mobility services scenario)	(a) 12558 (b) 6748	(a) Average LCV mileage taken from DfT statistics (b) Taken from Carplus survey	(a) DfT (b) Carplus
Fuel efficiency (a) Diesel and petrol (b) PHEV (c) PEV	(a) Varies by Euro class of vehicle (b) 4km/kWh (c) 7km/kWh	(a) Average taken from 3 best-selling cars between Euro classes (b) & (c) Taken from 3 bestselling cars in 2017	Carfuel data
Fuel prices	Diesel, petrol and electricity retail price projections	Retail fuel price projections taken from BEIS	BEIS, 2017
Mobility service scenario: assumed proportion of new car demand met by car sharing scheme	10%	Ecuity assumption.	Ecuity assumption.
Emission Performance Assumptions			
NOx emission factor (gNOx/km)	(a) Diesel: 0.6 - 1, Petrol: 0.06 - 0.20 (b) EV: 0	(a) Varies by Euro standard. Taken from European Environment Agency. (b) EV's have assumed 0 Nox	(a) European Environment Agency
NOx damage cost (£/tNOx)	£16,361	Rural/urban NOx damage cost taken from DEFRA, and weighted for proportion of car traffic on urban/rural roads (DfT stats)	DEFRA – adjusted to 2017 prices.
GHG emission factor (gCO2e/km)	(a) Diesel: 94 - 158, Petrol: 122 - 172 (b) EV: 0	(a) Varies by Euro standard. Taken from DfT data on car performance (b) EV's have assumed 0 tailpipe GHG emissions	Carfuel data
GHG emission factor	£65.55 - £72.25/tCO2e over the 10 year period	Non-traded cost of carbon for 2018-2027 adjusted to 2017 prices	BEIS, 2017
Capital Cost Assumptions			
Capital cost of cars	Petrol & Diesel: £23,000-£24,000; EV: £32,000 - £23,000	Capex assumptions adapted from Bloomberg New Energy Finance projection	BNEF, 2017
Cost of EV infrastructure (£/car)	£381	Cost of slow EV charger adjusted for annual demand per LCV (taken from BEIS)	Zapmap, 2017
Other Assumptions			
Discount rate	3.5%	Future costs and benefits discounted to 2017 prices	HM Treasury – Green Book
Health impact uplift factor	2%	Future health benefits (reduced NOx) uplifted to reflect increased WTP with economic growth	HM Treasury – Green Book

LCV model

The LCV model estimates the costs and benefits of an expedited switch away from diesel vehicle demand, to petrol, EV or gas alternatives.

Model parameters	Value	Comment	Source
Vehicle Demand Assumptions			
Number of LCV registered - population	4mn (2018) - 4.5mn (2027)	Increases over 10 year period in line with trends in LCV demand. Driven by increased home delivery demand etc.	(a) DfT & Ecuity projection
New LCV registered per year	400,000 - 470,000/year	Increases over 10 year period with increased LCV demand	Ecuity assumption.
LCVs scrapped per year	6% of population	Oldest vehicles scrapped first. Estimated from DfT registration statistics. Steady over period.	(a) DfT & Ecuity projection
Business as Usual (BAU) technology demand	Diesel - 94%, Petrol - 4%, EV & Gas <1%	Based on DfT LCV registered statistics	(a) DfT & Ecuity projection
Diesel phase-out model: new LCV technology demand	Petrol 98% (2018) - 82% (2027) Gas and EV 2% (2018) - 18% (2027)	As diesel is phased-out, the proportion of demand attributed to alternatives	Ecuity assumption.
Operating Cost Assumptions			
Annual average mileage (km)	20,930	Average LCV mileage taken from DfT statistics	DfT
Fuel efficiency (a) Diesel and petrol (b) Gas LCV (c) BEV LCV	(a) Varies by Euro class of vehicle (b) 3.78 MJ/km (c) 0.17 kWh/km	Gas assumption taken from Ricardo AEA report. EV assumption based on best-selling European LCV https://www.transportenvironment.org/sites/te/files/publications/2016_02_TE_Natural_Gas_Biomethane_Study_FINAL.pdf	(a) DfT - http://vanfueldata.dft.gov.uk/ (b) Ricardo assumption (page 50) (c) Calculated from Nissan e-NV200
Fuel prices	(a) Diesel, petrol and electricity retail price projections (b) CNG: £20.5/GJ	(a) Retail fuel price projections taken from BEIS https://www.gov.uk/government/publications/valuation-of-energy-use-and-greenhouse-gas-emissions-for-appraisal (b) CNG price converted to £ and adjusted for VAT and fuel duty	(a) BEIS, 2017 (b) Ricardo asssumption
EV limited range penalty (/LCV/year)	£839	Given current EV LCV range (170km - based on Nissan e-NV200) and a typical distribution of daily mileage requirements, an estimation of forgone economic activity due to charging and limited range	Ecuity assumption.
Emission Performance Assumptions			
NOx emission factor (gNOx/km)	(a) Diesel: 0.125 - 1, Petrol: 0.07 - 0.21 (b) Gas: 0.07 (c) EV: 0	(a) Varies by Euro standard. Taken from the EQUA Index - real world emission testing (b) Assumption from Ricardo AEA study (c) EV's have assumed 0 Nox	(a) EQUA Index (b) Ricardo assumption
NOx damage cost (£/tNOx)	£15,333	Rural/urban NOx damage cost taken from DEFRA, and weighted for proportion of LCV traffic on urban/rural roads (DfT stats)	DEFRA – adjusted to 2017 prices.
GHG emission factor (gCO2e/km)	(a) Diesel: 113 - 185, Petrol: 133 - 190 (b) Gas: 227 (c) EV: 0	(a) Varies by Euro standard. Taken from DfT data on LCV performance (b) Assumption from Ricardo AEA study (c) EV's have assumed 0 tailpipe GHG emissions	(a) DfT (b) Riacrdo assumption
GHG emission factor	£65.55 - £72.25/tCO2e over the 10 year period	Non-traded cost of carbon for 2018-2027 adjusted to 2017 prices	BEIS, 2017
Capital Cost Assumptions			
Capital cost of LCVs	(a) Petrol: £14,325; Diesel: £15,511; Gas: £16,149 (b) EV: £17,637 - £15,013	(a) Ricardo assumption (page 48) (b) Nissan e-NV200 with a capex reduction factor applied interpreted from BNEF EV capex analysis	(a) Ricardo assumption (b) Nissan
Cost of EV infrastructure (£/LCV)	£381	Cost of slow EV charger adjusted for annual demand per LCV (taken from BEIS)	Zapmap, 2017
Cost of Gas infrastructure (£/LCV)	£136	Ricardo assumption adjusted to £	Ricardo assumption
Other Assumptions			
Discount rate	3.5%	Future costs and benefits discounted to 2017 prices	HM Treasury – Green Book
Health impact uplift factor	2%	Future health benefits (reduced NOx) uplifted to reflect increased WTP with economic growth	HM Treasury – Green Book

HGV model

Diesel HGVs are the dominant technology type in this segment. The HGV model considers costs and benefits of switching away from diesel HGVs to biomethane or dual-fuel (CNG/diesel) alternatives. The literature has not conclusively demonstrated NOx emission savings over euro 6 class vehicles[15], and therefore we have assumed no NOx savings made by gas HGVs over diesel euro 6 vehicles.

Model parameters	*Value*	Comment	Source
Vehicle Demand Assumptions			
Number of HGV registered - population	480,000	HGV demand fluctuates over last 10 years, but remains around ~500k	(a) DfT & Ecuity projection
New HGVs registered per year	39000	Assume stays steady over 10 year period	Ecuity assumption.
HGVs scrapped per year	8% of population	Oldest vehicles scrapped first. Estimated from DfT registration statistics. Steady over period.	Ecuity assumption.
Business as Usual (BAU) technology demand	Diesel - 99%, CNG - 1%, EV 0%	Based on DfT HGV registered statistics	(a) DfT & Ecuity projection
Diesel phase-out model: new HGV technology demand	Biomethane 50% and dual-fuel HGV 50%	Assumed that demand is split between biomethane and dual-fuel HGVs	Ecuity assumption.
Operating Cost Assumptions			
Annual average mileage (km)	55,673	Average HGV mileage taken from DfT statistics	DfT
Fuel efficiency (a) Diesel (b) Biomethane HGV (c) Dual-fuel HGV	(a) Varies by Euro class of vehicle 3.78-3.57 (km/l) (b) 0.0136 GJ/km (c) 8.5 miles/gallon	(a) DfT analysis (b) Ricardo assumption (c) Cenex for DfT	(a) Gov (b) Ricardo assumption. (c) Cenex for DfT
Fuel prices	(a) Diesel retail price projections (b) CNG: £20.5/GJ (c) Biomethane: 23.1/GJ	(a) Retail fuel price projections taken from BEIS (b) and (c) prices taken from Ricardo study and adjusted for VAT and fuel duty	(a) BEIS, 2017 (b) and (c) Ricardo asssumption
Additional fixed gas HGV operating cost (/LCV/year) (a) Biomethane (b) Dual-fuel	(a) £400 (b) £1100	Additional maintenance for gas vehicles	Cenex for DfT
Emission Performance Assumptions			
NOx emission factor (gNOx/km)	(a) Diesel: 0.49 - 8.4, Petrol: 0.07 - 0.21 (b) Dual-fuel and Biomethane: 0.49	No evidence available that gas HGVs have lower NOx than euro 6 diesel HGVs	Gov
NOx damage cost (£/tNOx)	£10,281	Rural/urban NOx damage cost taken from DEFRA, and weighted for proportion of HGV traffic on urban/rural roads (DfT stats)	DEFRA – adjusted to 2017 prices.
GHG emission factor (gCO2e/km)	(a) Diesel: 714 - 757 (b) Biomethane: 64 (c) Dual fuel: 778	(a) Varies by Euro standard. Taken from DfT data on LCV performance (b) Assumption from Ricardo AEA study (c) EV's have assumed 0 tailpipe GHG emissions	(a) Gov (b and (c) Ricardo assumption.
GHG emission factor	£65.55 - £72.25/tCO2e over the 10 year period	Non-traded cost of carbon for 2018-2027 adjusted to 2017 prices	BEIS, 2017
Capital Cost Assumptions			
Capital cost of HGVs	(a) Diesel: £67,426 (b) Biomethane: £98,426 (c) Dual-fuel gas HGV: £92,926	(a) Ricardo assumption (page 48) and (b) and (c) Cenex DfT assumption (page 41)	(a) Ricardo assumption (b) and (c) Cenex for DfT
Cost of Gas infrastructure (£/LCV)	£1,630	Ricardo assumption adjusted to £	Ricardo assumption
Other Assumptions			
Discount rate	3.5%	Future costs and benefits discounted to 2017 prices	HM Treasury – Green Book
Health impact uplift factor	2%	Future health benefits (reduced NOx) uplifted to reflect increased WTP with economic growth	HM Treasury – Green Book

[15] Cenex for DfT (2016) *Low Carbon Truck and Refuelling Infrastructure Demonstration Trial Evaluation.* Available from: https://www.gov.uk/